TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 488

A COMPLETE TANK TEST OF A FLYING-BOAT HULL WITH A POINTED STEP - N.A.C.A. MODEL NO. 22

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SUMMARY

The results of a complete tank test of a model of a flying-boat hull of unconventional form, having a deep pointed step, are presented in this note. The advantage of the pointed-step type over the usual forms of flying-boat hulls with respect to resistance at high speeds is pointed out.

A take-off example using the data from these tests is worked out, and the results are compared with those of an example in which the test data for a hull of the type in general use in the United States are applied to a flying boat having the same design specifications. A definite saving in take-off run is shown by the pointed-step type.

INTRODUCTION

Typical curves of the take-off characteristics of a flying boat show two regions in which the excess thrust available for acceleration is notably low. The first occurs at the "hump" of the resistance curve, in the low-speed part of the planing range, usually at about 30 percent of the get-away speed. The second occurs near the get-away speed. A large part of the take-off time is spent in accelerating through these regions of low excess thrust. The high speed obtaining during the second period of low acceleration causes the distance run during the last few seconds before get-away to be excessively great. A decrease in the high-speed resistance consequently causes a pronounced reduction in the length of the take-off run, and reduces the probability of damage to the hull when a take-off is made in rough water.

The designer has some control over the relative magnitude of the resistance in the two critical regions, as was pointed out in reference 1. Using a small hull for a given load is favorable to low resistance at high speeds, but unfavorable in the hump region. The resistance at the hump, however, is more critically dependent upon hull loading than that at high speeds. If a design shows a tendency to "stick" near get-away it can be improved to some extent by decreasing the hull size, thus increasing the value of the load coefficient and hence the ratio of load to resistance. If the high-speed resistance of the hull is excessively great, however, the necessary reduction in size may be great enough to cause seriously high resistance at the hump.

Consideration of these characteristics led to the conclusion that the over-all performance of a flying-boat hull could be materially improved if some means could be found of obtaining a large reduction in high-speed resistance without materially affecting the hump resistance. This method of attack seemed particularly logical since the ratio of load to resistance at high speeds and light loads is distinctly low for hulls of conventional form, whereas that for the hump region is already reasonably high and could be made still higher simply by increasing the size of the hull if doing so did not cause trouble near get-away.

This line of reasoning is probably responsible for several designs incorporating longitudinal steps or fluted bottoms for the purpose of reducing the effective beam and consequently the resistance at high speeds. From the rather meager data available on such types it appears that they only partly accomplish this purpose, and that the ratio of load to resistance in the high-speed range is but slightly better than that for a conventional hull. A possible explanation may lie in the fact that most of the high-speed resistance seems to be caused by the blister from the step striking the afterbody. This explanation is borne out by unpublished tests made in the N.A.C.A. tank on a forebody alone, in which the resistance at high speeds and light loads was considerably less than that of the same hull with the afterbody in place. Although the longitudinal step is effective in reducing the wetted beam of the forebody, the blister raised aft of the step is probably not appreciably smaller than that arising from a plain V bottom, hence the resistance of the afterbody is not materially reduced.

A somewhat different solution to the problem was suggested by the behavior of a conventional hull running in the high-speed range at very high trim angles. Under these conditions the step came clear of the water and the load was carried on the pointed afterbody, with about half the resistance of the same hull running at the best trim angle with the load on the step. This condition is represented by the curves for loads of 5 and 10 pounds, and by one point for a 20-pound load, in figure 6 of reference 1. The trim angle of the base line for these curves was 9°, and the angle between the base line and the afterbody keel 5.5°, causing the afterbody to run at an angle of 3.5°. The clearance of the tail extension was great enough that the blister from the afterbody did not touch it.

The condition described had no direct application for the hull in question, because the diving moments exerted by the water reaction were outside the practical limit. It did, however, suggest the possibility of designing a hull with a pointed step, making the step deep enough to keep the afterbody clear at high speeds. It was believed that the air drag of a deep pointed step, with the chines fair in plan form, would be no worse than that of a conventional transverse step. It also seemed probable that the dead rise could be made small without causing severe landing shock, since the landing would be made on the point of the step.

A set of lines was laid out in accordance with these ideas, and N.A.C.A. model 22 was made from them. It was tested by the "complete" method in the N.A.C.A. tank during July 1933.

APPARATUS AND METHODS

The procedure and purpose of the complete type of test used in the present investigation are discussed in detail in reference 1. The method consists of towing the model at all the combinations of speed, load, and trim angle that lie within the useful working range. For each test point the resistance, trimming moment, and draft corresponding to one combination of the independent variables are measured.

The towing gear used in the present tests differs slightly from that described in reference 2. The apparatus for measuring resistance and moments is retained, but the method of suspending the model has been somewhat altered. The new apparatus, together with other changes now being considered, will be described in a future report.

Description of a Model

The lines and offsets of model 22 are shown in figure 1. The essential differences between this form and that of a conventional hull lie in the deep pointed step, the horizontal afterbody, and the low angle of dead rise. The bow is also unusually high and the buttocks rise rather sharply forward of the station of maximum beam. The tail extension aft of the sternpost was not incorporated in the model because its effect on water performance is believed to be slight. The lines as shown are suitable for use in a design where the tail surfaces are carried on outriggers. A tail extension may be added if it is desired to use these lines for a design in which the surfaces are carried on the hull structure. In this case the keel of the tail extension should meet the sternpost somewhat above water line 3 to avoid detrimental interference.

The model is constructed of laminated mahogany, hollowed out to reduce the weight. It is covered by a flat plywood deck. The finish consists of several coats of grey enamel, rubbed to a smooth surface.

The principal dimensions are:

Length, over-all	76 in.
Length of forebody	48 in.
Maximum beam	17 in.
Depth, over-all	12 in.
Depth of step	2.94 in.
Angle of dead rise	10°
Angle between keels	0°

RESULTS

Test data.- The load, speed, resistance trimming moment, and draft for each test point are given in the table of test data. All the points for one trim angle are tabulated together. The same data, with the exception of the drafts, are presented graphically in figures 2 to 7 as curves of resistance and trimming moment plotted against speed, with the load as a parameter. Each figure gives the results for one trim angle. The resistance given includes the air drag of the model, as was explained in reference 1. When the results are applied to a take-off calculation the parasite drag of the hull should not be included in the air drag of the seaplane.

The trimming moments and drafts at rest are given in figures 8 and 9. These curves may be used to determine the water line at rest for any displacement and center-of-gravity position. The trimming-moment curves also give the longitudinal stability of the hull at rest.

Nondimensional results.- The difficulties caused by the large number of variables in the test data, and a method of avoiding them, are discussed in reference 1. The procedure consists of plotting the model resistance for a given speed and load against trim angle, to determine the minimum resistance and the best trim angle for that particular speed and load. Cross-plots of minimum resistance and best trim angle against load are then prepared for each speed. The results are reduced to nondimensional form and presented as curves of resistance coefficient and best trim angle against speed coefficient, with load coefficient as a parameter. The trimming moments are similarly plotted against trim angle for a given load and speed, and the moment corresponding to the best trim angle read from the curve. These moments are then reduced to nondimensional form and plotted against load with speed as a parameter. The moment coefficients corresponding to even load coefficients are read from these curves and the results presented as curves of trimming-moment coefficients plotted against speed coefficient with load coefficient as a parameter.

The nondimensional coefficients are used only in the presentation of data for the best trim angles. They are defined as follows:

Load coefficient, $C_\Delta = \frac{\Delta}{w\ b^3}$

Resistance coefficient, $C_R = \frac{R}{w\ b^3}$

Trimming-moment coefficient, $C_M = \frac{M}{w\ b^4}$

Speed coefficient, $C_V = \frac{V}{\sqrt{g\ b}}$

where	Δ	is the load on the water	lb.
	R,	water resistance	lb.
	w,	weight density of water	lb./cu.ft.
	b,	beam of hull	ft.
	M,	trimming moment	lb.-ft.
	V,	speed	ft./sec.
	g,	acceleration of gravity	ft./sec.^{2}

Note: w = 63.6 lb./cu.ft. for the water in the N.A.C.A. tank.

The nondimensional results showing the characteristics of model 22 at the best trim angles are presented in figures 10 to 13. Figures 11 and 12 both present the values of C_R as a function of C_V and C_Δ. Figure 11 is included to show the trend of C_R against C_V, whereas figure 12 is more readily applied to a take-off calculation.

Accuracy.- The test data as presented in the faired curves are believed to be correct within the following approximate limits:

Load	± 0.3 lb.
Resistance	$\pm$ .1 lb.
Speed	$\pm$ .1 ft./sec.
Trim angle	$\pm .1^{\circ}$
Trimming moment	± 1 lb.-ft.

DISCUSSION

Resistance characteristics.- The results show that the low resistance at high speeds and light loads expected of this model has been realized. Figure 11 shows reasonably flat curves of C_R against C_V in the high-speed range. The rise of C_R noted with increasing C_V is caused in part by the air drag of the model, which is included in the resistance. The actual water resistance is probably nearly constant against speed in this region.

An idea of the relative merit of this model can be obtained from figure 14, in which the value of the load-resistance ratio at various speed coefficients is plotted against load coefficient for models 22 and 11-A. Model 11-A, the characteristics of which are given in reference 3, has the best performance of any model so far tested by the complete method in the N.A.C.A. tank. It is believed to be a fair representative of well-designed hulls of the conventional American type. Figure 14 shows that model 22 is definitely inferior to model 11-A at the hump speed. At all the higher speeds chosen, however, the superiority of model 22 is considerable, amounting to a 73-percent increase in Δ/R over that of model 11-A for a speed coefficient of 6.0 and load coefficient of 0.1.

The relatively high hump resistance of model 22 does not appear to be inherent in the deep pointed step, but seems rather to be caused by the upward curvature of the buttocks toward the bow. A longer flat on the forebody forward of the step, together with a lower bow, will probably reduce the hump resistance to about the same value as that of good conventional types.

Moment characteristics.- In previous notes on hulls tested by the complete method in the N.A.C.A. tank, the moment coefficients at best angles have not been presented. The reason for this omission, explained in reference 1, was the difficulty presented by the rapid change of trimming moment with angle. The attempt to establish these curves for model 22 was somewhat more successful than the previous efforts, and the curves are presented in figure 13. The sign of the trimming moments follows the usual aerodynamic convention, i.e., moments that tend to raise the bow are considered positive. The use of this figure to determine the trimming moments necessary to maintain best trim angles throughout a take-off run consists of reading the value of C_M corresponding to the values of C_V and C_Δ for a given condition. The trimming moment is then,

$$M = C_M \ w \ b^4$$

where b is the full-scale beam in feet.

Spray formation.- The spray characteristics of model 22 were studied by direct observation and by means of photographs taken during the tests. At low speeds the hull is rather "dirty." The bow blister is heavy and rises to a considerable height. The upward curvature of the buttocks near the bow is apparently responsible for this undesirable blister as well as for the relatively high hump resistance at heavy loads. The height of the blister could probably be materially reduced by means of spray strips.

A pronounced roach, or feather, is raised behind the model at a speed of about 10 feet per second. The position and height of this roach vary with speed, and it disappears completely at speeds above about 12 feet per second. The addition of a tail extension of the usual form would probably serve to hold the roach down so that it would not damage the tail surfaces, without causing an appreciable change in resistance.

At high speeds and low angles the model is very clean. It runs on the forebody only, and the spray clears the afterbody entirely. This fact accounts for the low resistance in the high-speed region.

Take-off example.- The effect of the characteristics of model 22 on take-off performance can best be shown by working out an example. For this purpose the same design specifications that were used for the examples in references 1 and 3 are assumed. They are:

Gross load	15,000 lb.
Wing area	1,000 sq.ft.
Power	1,000 hp.
Effective aspect ratio, considering ground effect	7.0
Parasite drag coefficient, excluding hull	0.05
Airfoil	Clark Y (data taken from N.A.C.A. T.R. No. 352, p. 26)

The relatively high resistance of model 22 at the hump and the low resistance at high speeds lead to the selection of a low value of the load coefficient. A value of 0.3 at the hump corresponding to a Δ/R of 5.08 was chosen for the first trial. This selection is based upon inspection of the curves of figure 14. A second trial may be required after the curves of total resistance and thrust available have been constructed if the excess thrust at either of the critical regions is too low. The load at the hump is assumed to be $0.9 \times \Delta_0$, or 13,500 pounds. The beam is thus $\left(\frac{13500}{0.3 \times 64}\right)^{1/3}$ or 8.9 feet.

The wing setting is determined by the method outlined in reference 1. The setting giving the least total resistance at 85 percent of the stalling speed is 6.3°, corresponding to an angle of attack of 10.5° and a best trim angle of 4.2°.

The curve of the total air-plus-water resistance, based on these conditions, is given in figure 15(a), together with the curve for model 11-A taken from reference 3. The thrust curve in this figure is the same as that used in the previous examples of references 1 and 3. The curves of $1/a$ and V/a, computed from the excess thrust available for acceleration shown by figure 15(a), are plotted in figure 15(b). The area under the curve of $1/a$ represents take-off time, and that under the curve of V/a take-off run. Comparison of the V/a curves of the two models shows clearly the superiority of model 22 in reducing the length of run at high speeds.

It may appear from the curves of figure 15(a) that a better choice of beam could have been made for either or both models. Model 22 shows considerably lower excess thrust at the hump than at high speed, while the converse is true of model 11-A. Several trial calculations using different beams were made, however, and those chosen appear to give about the best performance possible in each case. A further increase in the beam of the model 22 hull would cause the weight and air drag of the hull to be excessively high. Some of the advantage of the low water resistance at high speeds would also be sacrificed. If the beam of the model 11-A hull were reduced the hump resistance, and therefore the take-off time, would be increased without a proportionate decrease in high-speed resistance. The forms of the curves are inherent in the characteristics of the two models, rather than in the selection of beams for this example.

A comparison between the results of the two hulls applied to the design conditions assumed is given in the following table:

	Model 22	Model 11-A
Beam	106.8 in.	96.3 in.
Angle of wing setting	6.3°	6.7°
Take-off time	36.8 sec.	38.4 sec.
Take-off run	2,090 ft.	2,408 ft.

The get-away speeds for the two hulls in the example are not exactly the same, as may be seen from figure 15(a). This discrepancy arises from the fact that the trim-angle curve for the run just preceding take-off is assumed to be an extrapolation of the curve up to the last point actually calculated. The trim angles as well as the wing setting for model 22 were slightly lower than those for model

11-A, hence the get-away speed is higher. In an actual take-off the get-away for either hull could be made at a speed lower than that shown, but still above the stalling speed, by means of an abrupt pull-off. This phase of the problem and its effect on time and run is discussed in detail in reference 4.

The best trim angles for the example using the model 22 hull, and the moments required to hold those angles, are plotted against speed in figure 16. The trim angles are obtained as a part of the take-off calculations and the moments are read from the curves of figure 13 in the manner described in the discussion of that figure. The center about which the moments are taken is shown in figure 1. The thrust and aerodynamic moments should next be added to the water moments, to ascertain whether the control is adequate. Unless these external moments are strongly negative, it appears that the center of gravity of a flying boat using the lines of model 22 should be farther forward than the center of moments shown in figure 1, since the water moments alone are decidedly positive (stalling) throughout most of the speed range.

CONCLUDING REMARKS

The present tests show the possibility of improving the water performance of flying-boat hulls by departure from the conventional designs. Further work on hulls of the type of model 22 is under way. The next step in the development is a study of the effect of a forebody having a longer flat and a lower bow, in an attempt to reduce the hump resistance for a given value of C_Δ, so that a smaller hull may be used.

Wind-tunnel tests are required to determine whether the air drag of the pointed-step type is reasonably low. In this connection, a general study of the effect of bottom shapes on air drag would be of value.

Experiments with designs of the same general type as model 22, but with greater ratios of length to beam, may lead to the development of forms suitable for use in twin-hull flying-boat and float-seaplane designs. Various angles of dead rise should also be tested in order to determine how great the dead rise may be made on this type of hull without seriously increasing the resistance.

Full-scale experiments with a small and inexpensive flying boat would be of great value in determining the landing characteristics of the pointed-step hull, as well as its tendency to porpoise. These qualities cannot be investigated satisfactorily in the towing tank, although general considerations lead to the expectation that the pointed-step type will be at least as satisfactory in these respects as hulls of conventional form. Some tendency toward directional instability was noted at low speeds and heavy loads for the hull tested. This tendency persisted over a very small range of speeds and would probably not cause any difficulty; however, full-scale experiments are also necessary for determining whether the hull is entirely satisfactory in this respect.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 18, 1933.

REFERENCES

1. Shoemaker, James M., and Parkinson, John B.: A Complete Tank Test of a Model of a Flying-Boat Hull - N.A.C.A. Model No. 11. T.N. No. 464, N.A.C.A., 1933.

2. Truscott, Starr: The N.A.C.A. Tank - A High-Speed Towing Basin for Testing Models of Seaplane Floats. T.R. No. 470, N.A.C.A., 1933.

3. Parkinson, John B.: A Complete Tank Test of a Model of a Flying-Boat Hull - N.A.C.A. Model No. 11-A. T.N. No. 470, N.A.C.A., 1933.

4. Shoemaker, James M., and Dawson, John R.: The Effect of Trim Angle on the Take-Off Performance of a Flying Boat. T.N. No. 486, N.A.C.A., 1934.

TABLE

Test Data for N.A.C.A. Model No. 22 Flying-Boat Hull

Kinematic viscosity = 0.000011 ft.^{2}/sec.
Water density, 63.6 lb./cu.ft. Water temperature, 69° F.

Note: Positive moments tend to raise the bow

Trim angle, τ = 2°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
5	25.3	1.8	1	0.7
	27.8	1.9	-1	.7
	32.4	2.0	-1	.6
	38.5	2.7	-1	.6
	43.8	2.3	-2	.5
	49.0	3.0	-2	.6
	55.0	3.3	-4	.4
10	25.4	2.7	4	.8
	27.8	2.9	3	.8
	32.8	3.2	1	.8
	38.4	3.1	0	.6
	43.8	3.9	-1	.7
	49.0	4.0	-2	.6
	55.0	4.3	-3	.6
20	38.5	5.8	5	.9
	42.5	5.9	4	.7
	49.0	6.4	1	.8
	53.5	6.8	-1	.6
40	7.8	6.8	27	3.7
	9.4	8.3	30	4.7
60	7.9	10.2	42	4.7
	9.4	12.4	44	4.7
80	7.8	13.2	54	5.6
	9.4	16.2	55	5.5
100	7.8	16.6	60+	6.5

Trim angle, τ = 3°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
5	20.0	.9	0	0.9
	23.0	1.0	0	.7
	26.0	1.3	-1	.7
	31.0	1.6	-1	.5
	36.9	1.7	-2	.5
	41.1	1.9	-2	.4
	46.6	2.1	-2	.4
	52.0	2.5	-2	.2
10	19.0	1.7	5	1.3
	20.6	1.7	3	1.1
	22.8	1.8	4	1.1
	23.0	1.8	1	.9
	26.0	2.1	0	.7
	31.2	2.3	-1	.6
	36.0	2.6	-2	.6
	41.8	2.7	-2	.6
	46.5	3.2	-2	.6
	52.2	3.2	-4	.5
20	13.6	3.8	22	2.1
	15.2	3.5	21	1.9
	17.0	3.4	19	1.7
	19.0	3.3	17	1.7
	20.5	3.2	12	1.6
	22.8	3.4	10	1.5
	23.2	3.4	8	1.3
	26.0	3.6	8	1.1
	31.1	3.8	-1	.9
	36.1	4.1	1	.7
	41.7	4.3	0	.8
	46.8	4.8	-2	.8
	52.0	5.3	-4	.7
40	6.4	5.2	14	4.0
	8.2	7.1	23	3.9
	9.8	8.1	23	3.6
	16.9	11.4	>62	2.9
	18.7	10.2	58	2.7
	20.3	8.4	49	2.3
	22.8	7.2	46	2.1
	23.2	7.0	38	1.8
	25.9	6.9	30	1.6
	31.0	7.0	23	–
	30.8	7.0	23	1.3
	36.2	7.7	16	1.3
	42.0	8.0	9	1.0
	45.3	8.1	7	.9
60	6.4	7.2	20	4.8
	8.2	11.0	37	4.8
	9.5	12.5	35	4.6
	25.3	12.6	64+	2.2
	32.0	9.7	41	1.6
80	6.4	9.1	26	5.7
	8.2	14.4	48	5.7
	32.3	14.3	66+	2.1
100	6,3	10.7	31	6.4

Trim angle, τ = 5°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
5	20.9	.9	-2	0.7
	22.7	.9	-2	.7
	25.2	1.1	-2	.6
	28.0	1.3	-2	.4
	32.8	1.7	-3	.4
	38.6	2.1	-4	.5
	42.9	2.4	-4	.2
	47.7	2.7	-4	.3
	52.8	3.4	-4	.4

TABLE (Continued)

Test Data for N.A.C.A. Model No. 22 Flying-Boat Hull

Kinematic viscosity = 0.000011 ft.^{2}/sec.
Water density, 63.6 lb./cu.ft. Water temperature, 69° F.
Note: Positive moments tend to raise the bow

Trim angle, τ = 5°					Trim angle, τ = 5°				
Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.	Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
10	19.0	1.5	0	1.2	80	7.3	12.7	25	6.0
	20.9	1.5	-1	1.1		9.2	16.3	31	5.8
	22.6	1.6	-2	.9		23.0	14.3	63+	2.8
	25.4	1.7	-2	.8		25.2	11.9	60+	2.2
	28.2	1.9	-2	.7		27.8	11.5	52	2.2
	32.7	2.3	-4	.1		33.0	11.4	34	1.7
	38.6	2.9	-4	.6	100	7.3	15.5	32	6.7
	43.3	3.0	-6	.5	Trim angle, τ = 7°				
	47.5	3.6	-6	.5	5	19.4	1.4	-3	1.0
	53.0	4.7	-9	.4		21.6	1.6	-3	.7
20	13.9	2.7	11	2.1		24.6	1.8	-4	.7
	15.6	2.8	11	1.8		27.0	2.2	-5	.6
	17.5	2.8	6	1.6		32.3	2.5	-5	.6
	19.0	2.8	5	1.6		38.0	3.3	-8	.4
	20.8	2.8	4	1.4		42.2	3.1	-10	.2
	22.6	2.8	3	1.2		45.5	2.9	-12	.1
	25.1	3.1	1	1.2		50.5	2.1	-14	0
	28.0	3.3	-1	1.1	10	18.2	1.9	-1	1.3
	32.5	3.9	-4	.7		19.3	2.0	-3	1.3
	38.5	4.2	-5	.7		21.6	2.4	-3	.8
	42.4	4.7	-7	.6		24.8	2.6	-5	.7
	48.5	4.9	-10	.7		27.0	2.9	-6	.7
	52.8	6.2	-11	.5		32.2	3.6	-8	.7
40	7.3	6.2	7	4.1		37.4	4.4	-12	.6
	9.4	6.9	9	3.7		43.0	5.1	-12	.6
	10.9	7.4	12	3.5		47.5	5.7	-16	.3
	12.6	7.7	25	3.2		50.5	6.2	-14	.5
	13.8	7.8	34	3.1	20	13.0	3.0	0	1.9
	15.5	7.6	43	2.9		14.9	3.2	2	1.8
	17.6	6.1	35	2.5		16.3	3.2	3	1.7
	19.0	5.9	27	2.2		18.3	3.1	2	1.7
	20.8	5.7	23	2.1		19.4	3.3	1	1.7
	22.5	5.4	20	1.7		21.5	3.6	-1	1.3
	25.1	5.8	13	1.6		24.7	4.0	-4	1.0
	28.0	6.1	10	1.3		27.2	4.5	-6	.9
	32.6	6.0	3	1.1		32.3	5.3	-10	.8
	39.2	6.6	-2	1.0		37.9	6.0	-13	.7
	43.0	7.1	-6	1.0		42.8	6.8	-16	.7
	47.8	7.6	-8	.8		47.8	7.5	-19	.6
60	7.3	9.6	16	5.2		50.7	8.2	-19	.6
	9.2	11.6	20	4.8	40	6.5	5.8	-8	4.4
	10.8	12.8	21	4.5		8.3	6.7	-4	3.9
	12.6	14.6	35	4.1		9.9	6.7	-1	3.6
	13.8	16.0	55	4.2		11.5	6.6	5	3.3
	15.4	16.4	60+	4.1		12.9	6.5	14	3.1
	17.6	14.0	60+	3.5		14.8	6.4	23	2.8
	18.8	12.3	60+	3.3		16.0	6.3	23	2.6
	21.0	9.6	57	2.5		18.2	6.2	19	2.4
	22.1	8.9	50	2.3		19.4	6.1	16	2.3
	25.2	8.4	35	1.9		20.9	6.2	12	2.0
	27.9	8.5	26	1.7		21.6	6.2	10	1.9
	32.5	8.7	16	1.5		24.7	6.3	5	1.5
	39.4	9.1	4	1.2		26.9	6.9	2	1.4
	43.1	9.4	2	1.2		32.1	8.0	-5	1.3
						37.7	9.3	-12	1.0
						43.0	10.1	-19	1.0
						46.8	10.1	-21	.9

TABLE (Continued)

Test Data for N.A.C.A. Model No. 22 Flying-Boat Hull

Kinematic viscosity = 0.000011 ft.^{2}/sec.
Water density, 63.6 lb./cu.ft. Water temperature, 69° F.

Note: Positive moments tend to raise the bow

Trim angle, τ = 7°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
60	6.5	8.1	-5	5.4
	8.3	10.9	3	5.0
	9.8	12.0	6	4.7
	11.5	12.6	17	4.4
	12.9	12.6	30	4.1
	14.6	12.5	46	3.9
	15.9	11.5	54	3.6
	17.2	10.2	55	3.3
	18.0	9.9	51	3.0
	18.9	9.6	45	3.0
	19.2	9.6	43	2.6
	21.7	9.1	31	2.5
	24.5	9.2	22	1.9
	27.0	9.4	15	1.8
	32.3	10.1	4	1.6
	37.8	11.7	-6	1.4
80	6.4	10.0	-3	6.2
	8.4	15.5	11	5.9
	9.7	16.9	12	5.6
	17.7	17.8	68+	4.0
	19.5	14.5	60+	3.3
	21.6	12.8	60	2.8
	24.5	12.6	43	2.3
	28.9	12.4	33	2.4
	32.5	12.6	16	1.8
100	6.4	12.7	-2	6.9

Trim angle, τ = 9°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
20	13.5	3.5	-16	1.8
	15.0	3.6	-10	1.7
	16.9	3.9	-8	1.5
	18.5	4.3	-6	2.6
	20.1	4.6	-8	2.4
	22.0	4.8	-8	1.2
	24.6	5.3	-12	1.1
	27.3	5.6	-22	.9
	32.6	4.9	-41	.1
40	7.0	6.7	-18	4.2
	8.8	7.2	-15	3.9
	10.4	7.2	-12	3.5
	11.8	7.0	-8	3.1
	13.6	7.0	2	2.8
	14.8	7.2	4	2.6
	16.9	7.1	11	2.4
	18.5	7.2	7	2.4
	20.1	7.2	6	2.1
	22.0	7.4	4	1.8
	25.0	8.5	-4	1.6
	25.5	8.3	-3	1.5
	27.4	9.3	-9	1.5
	32.5	10.3	-23	1.2
60	7.0	9.9	-15	5.3
	8.6	11.7	-12	4.8
	10.3	12.5	-4	4.6
	11.8	12.0	6	4.2
	13.6	11.4	14	3.8
	14.8	11.2	25	3.6
	16.8	10.8	28	3.1
	18.4	10.9	28	2.9
	20.0	10.9	23	2.6
	22.0	10.8	18	2.2
	25.0	11.0	10	2.0
	25.6	10.6	8	1.9
	27.4	11.4	4	1.7
	31.8	13.4	-8	1.5
80	7.3	14.2	-10	6.2
	8.6	16.5	4	5.9
	10.2	18.5	2	5.6
	10.8	18.9	7	5.5
	12.1	18.6	22	5.3
	13.4	18.0	34	4.9
	14.8	17.5	46	4.5
	16.6	16.1	60	4.1
	18.4	14.8	58	3.5
	20.0	14.6	49	3.2
	22.0	14.4	40	2.7
	25.0	14.3	25	2.2
	27.0	14.3	21	2.2
	32.2	15.6	3	1.7
100	7.1	17.1	-5	7.3
	9.1	22.2	7	6.9

Trim angle, τ = 11°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
40	9.3	8.2	-24	3.6
	10.8	8.2	-23	2.7
	12.4	8.2	-21	2.9
	14.1	8.3	-20	2.4
60	9.2	13.4	-22	4.8
	10.9	12.7	-15	4.4
	12.4	12.4	-8	3.9
	14.1	12.4	-3	3.5
80	9.3	18.3	-16	5.9
	10.8	19.3	-4	5.5
	12.3	18.4	5	4.9
	14.0	17.6	15	4.4
	15.6	16.9	20	4.0
	17.3	16.8	24	3.5
	19.1	16.5	23	3.2

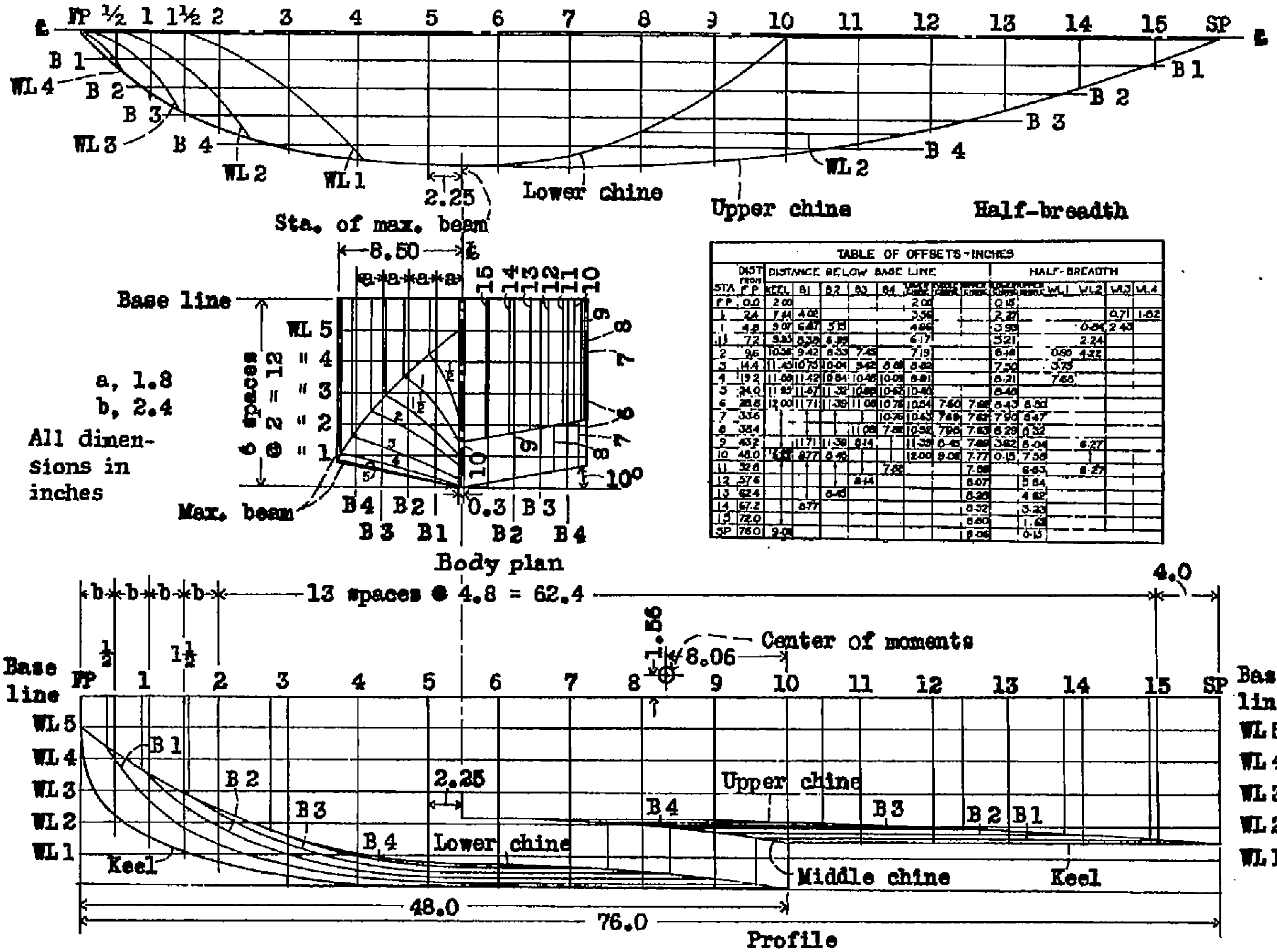

TABLE OF OFFSETS - INCHES

STA	DIST FROM F P	DISTANCE BELOW BASE LINE: KEEL	B1	B2	B3	B4	UPPER CHINE	MIDDLE CHINE	LOWER CHINE	HALF-BREADTH: UPPER CHINE	LOWER CHINE	WL 1	WL 2	WL 3	WL 4
F P	0.0	2.00					2.00			0.15					
½	2.4	7.44	4.02				3.56			2.27				0.71	1.62
1	4.8	9.07	6.47	5.15			4.86			3.99			0.84	2.43	
1½	7.2	9.83	8.38	6.89			6.17			5.21			2.24		
2	9.6	10.36	9.42	8.33	7.45		7.19			6.46		0.90	4.25		
3	14.4	11.43	10.75	10.04	9.42	8.68	8.62			7.50		3.75			
4	19.2	11.68	11.42	10.84	10.46	10.09	9.81			8.21		7.66			
5	24.0	11.87	11.67	11.32	10.88	10.65	10.40			8.46					
6	28.8	12.00	11.71	11.39	11.06	10.76	10.54	7.60	7.66	8.43	8.50				
7	33.6					10.76	10.63	7.69	7.62	7.90	8.47				
8	38.4				11.09	7.86	10.58	7.90	7.63	6.29	8.32				
9	43.2		11.71	11.39	8.14		11.39	8.45	7.69	3.62	8.04		6.27		
10	48.0	11.56	8.77	8.49			12.00	9.06	7.77	0.15	7.36				
11	52.8					7.85			7.86		6.63		6.27		
12	57.6				8.14				8.07		5.84				
13	62.4			8.46					8.26		4.62				
14	67.2		8.77						8.32		3.23				
15	72.0								8.60		1.62				
SP	76.0	9.06							9.06		0.15				

Figure 1.- Lines and offsets of N.A.C.A. Model 22.

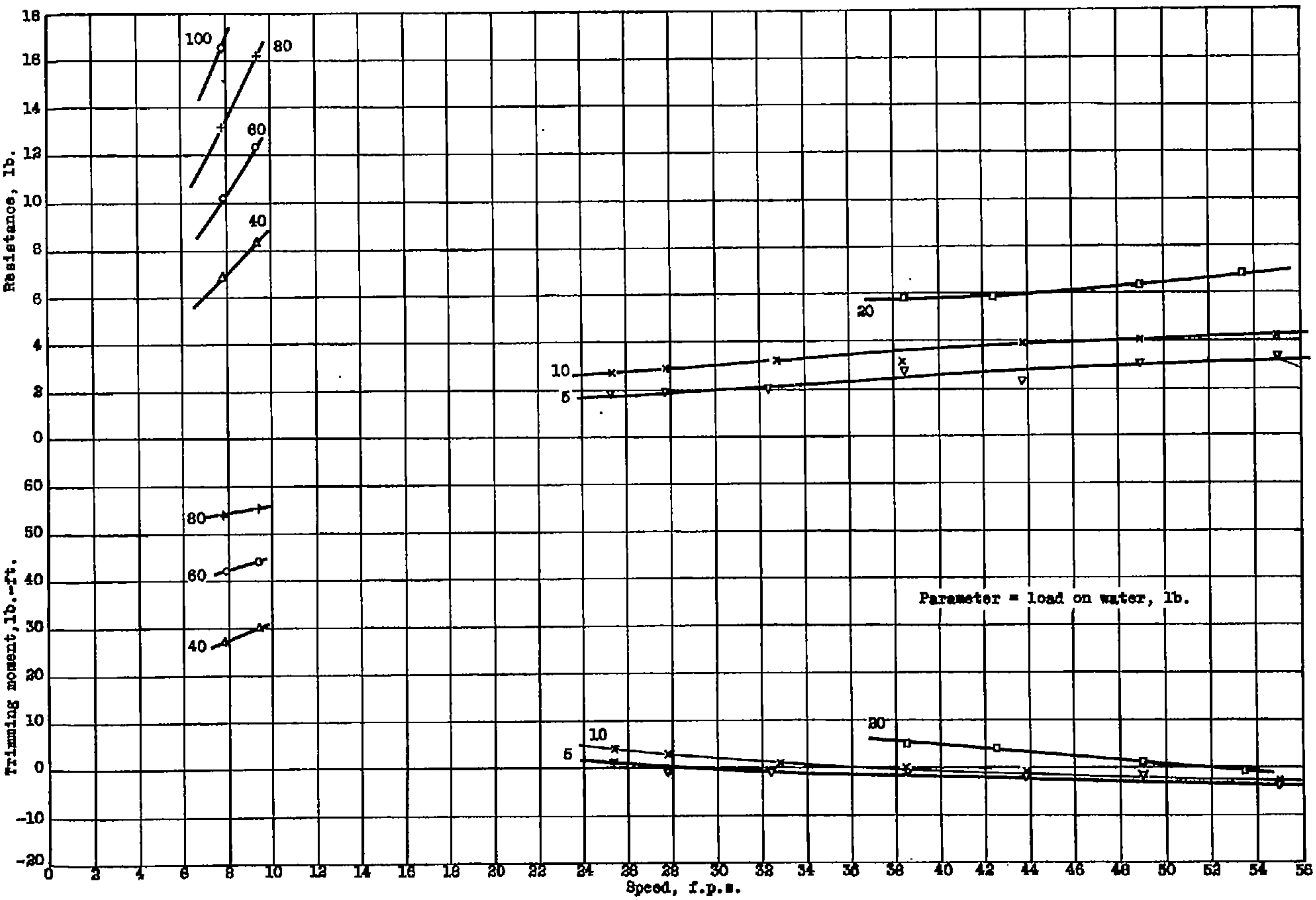

Figure 2.- Resistance and trimming moment, $\tau = 2^0$.
Model 22.

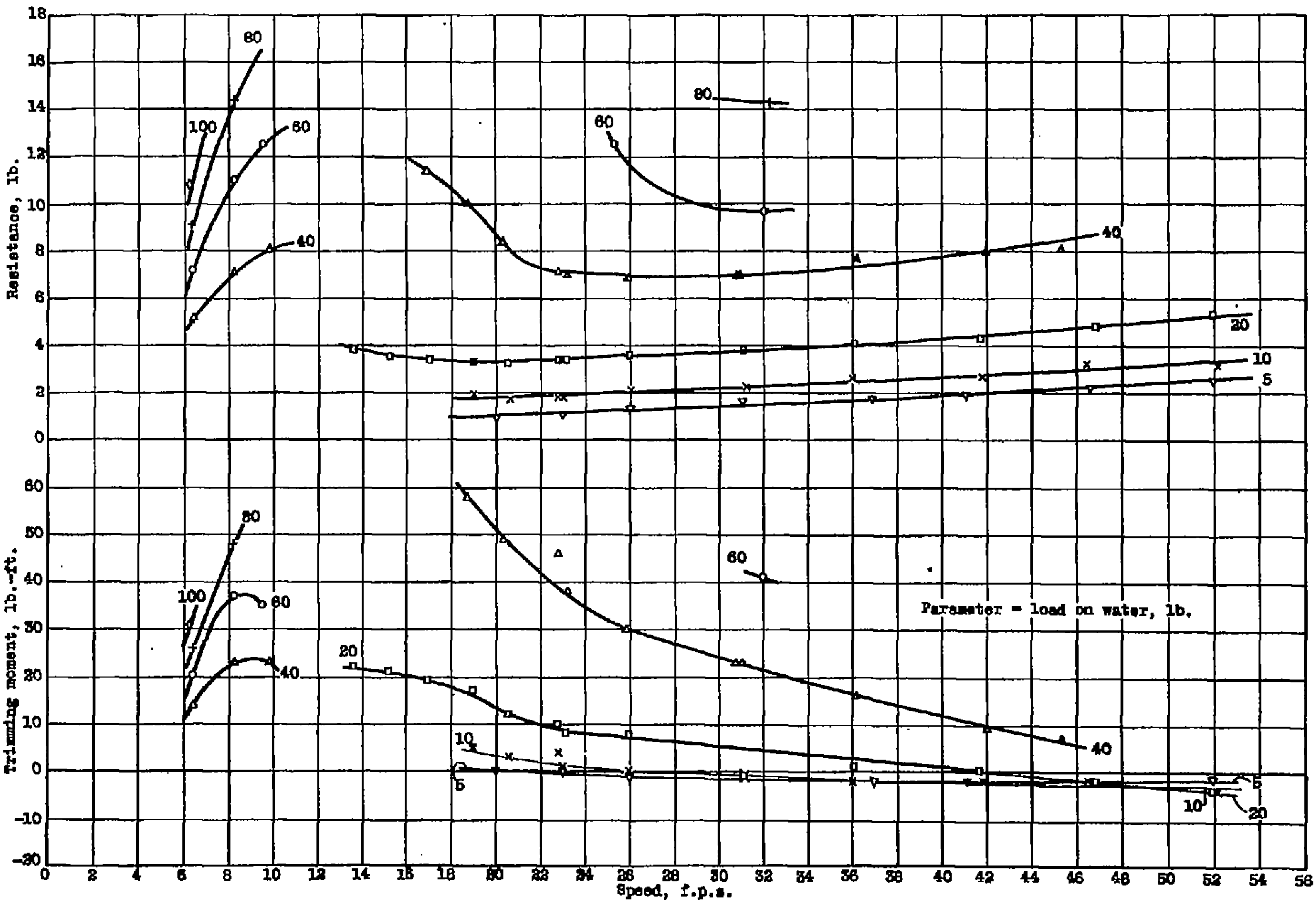

Figure 3.-Resistance and trimming moment. $\tau = 3^{\circ}$.
Model 22.

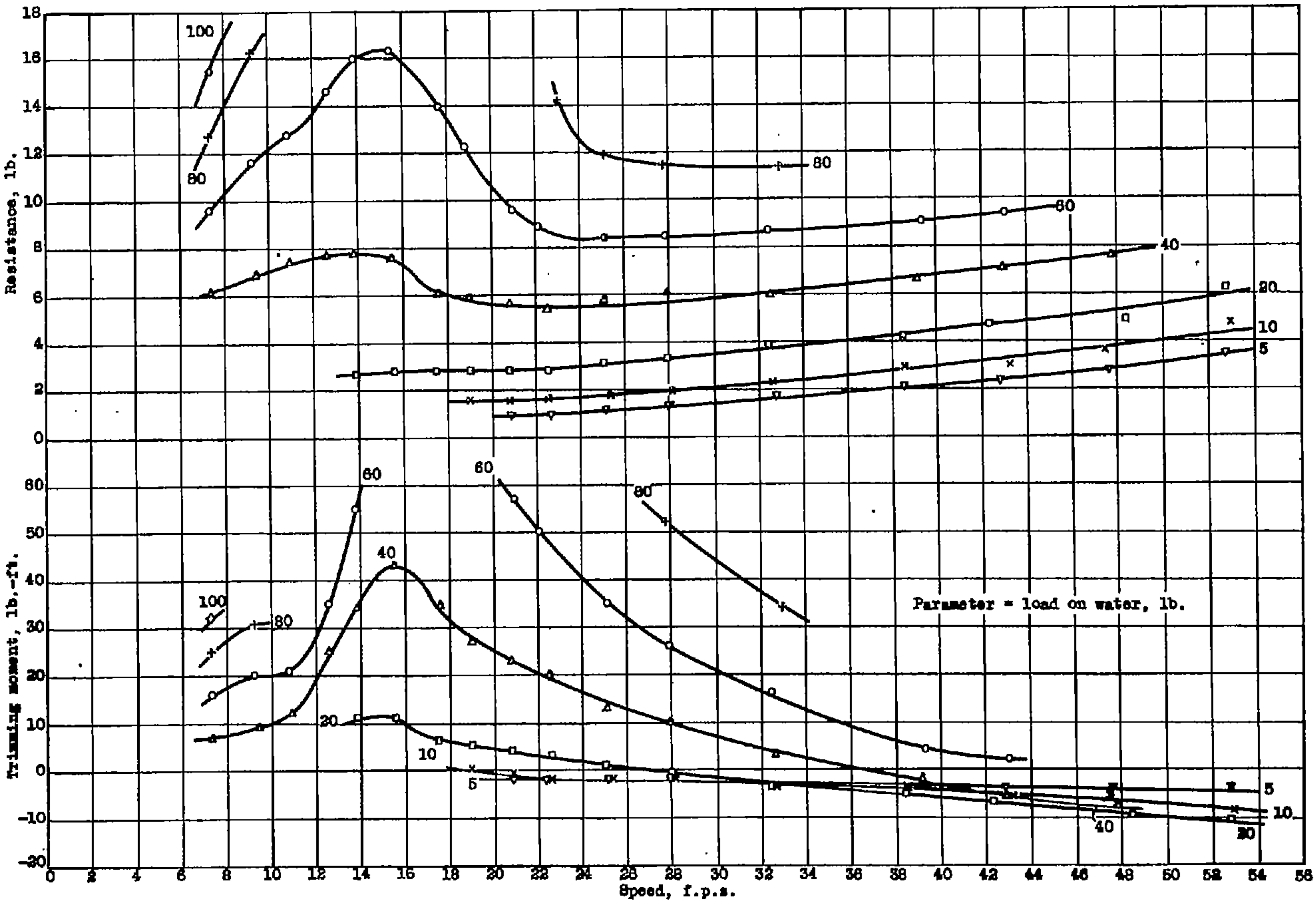

Figure 4.- Resistance and trimming moment. $\tau = 5^0$.
Model 22.

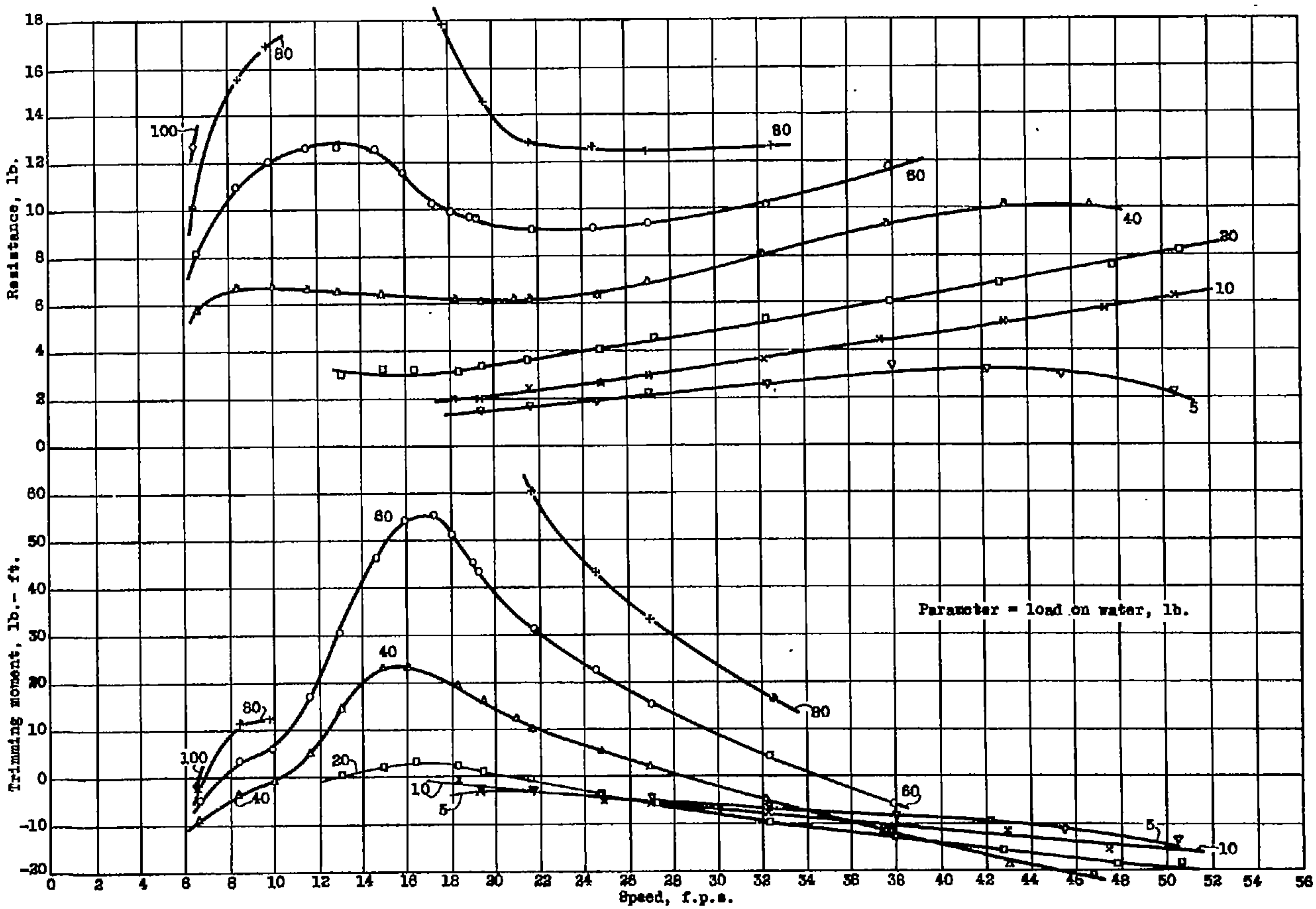

Figure 5.- Resistance and trimming moment. $\tau = 7^{\circ}$.
Model 22.

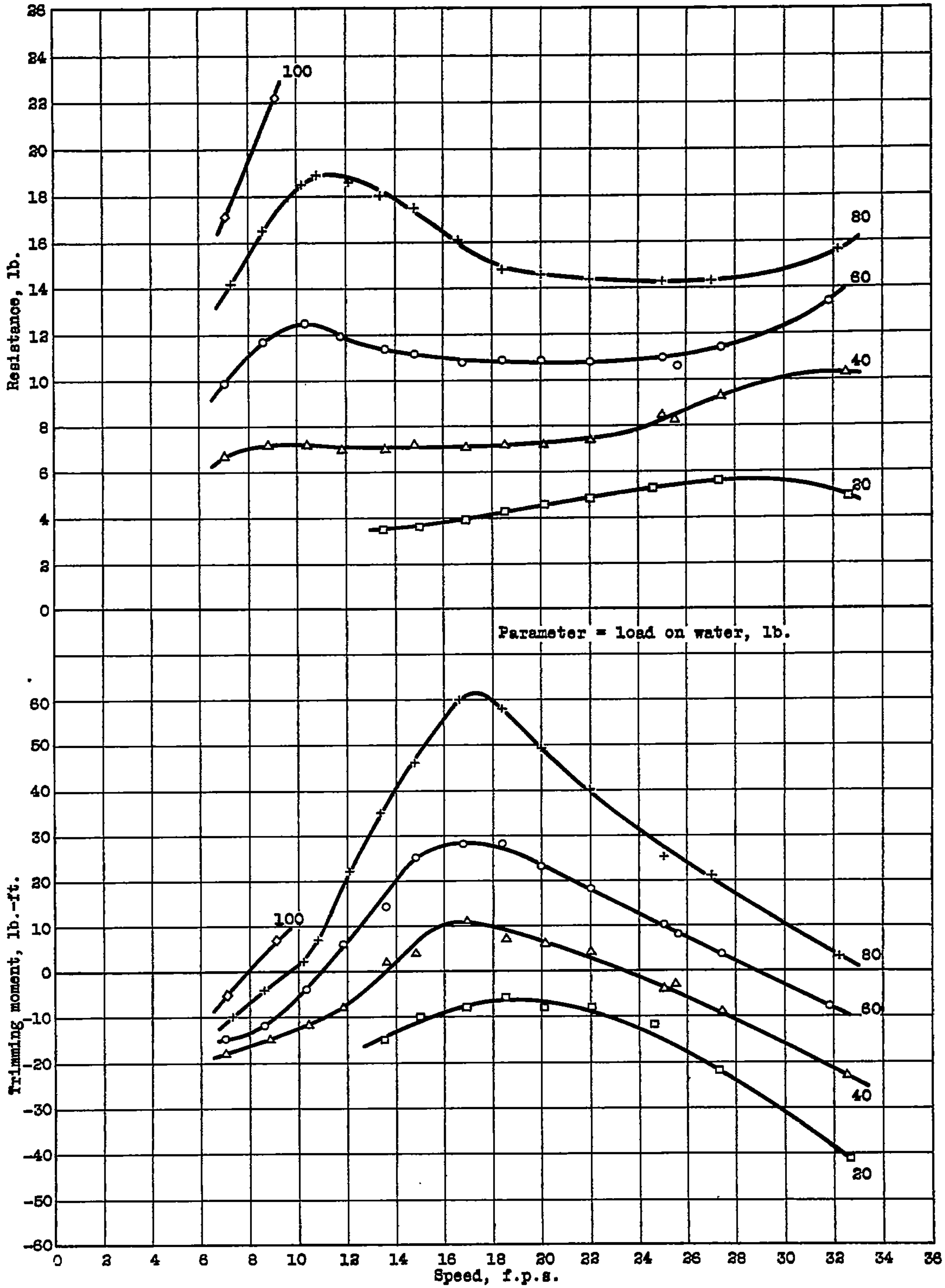

Figure 6.- Resistance and trimming moment. $\tau = 9°$.
Model 22.

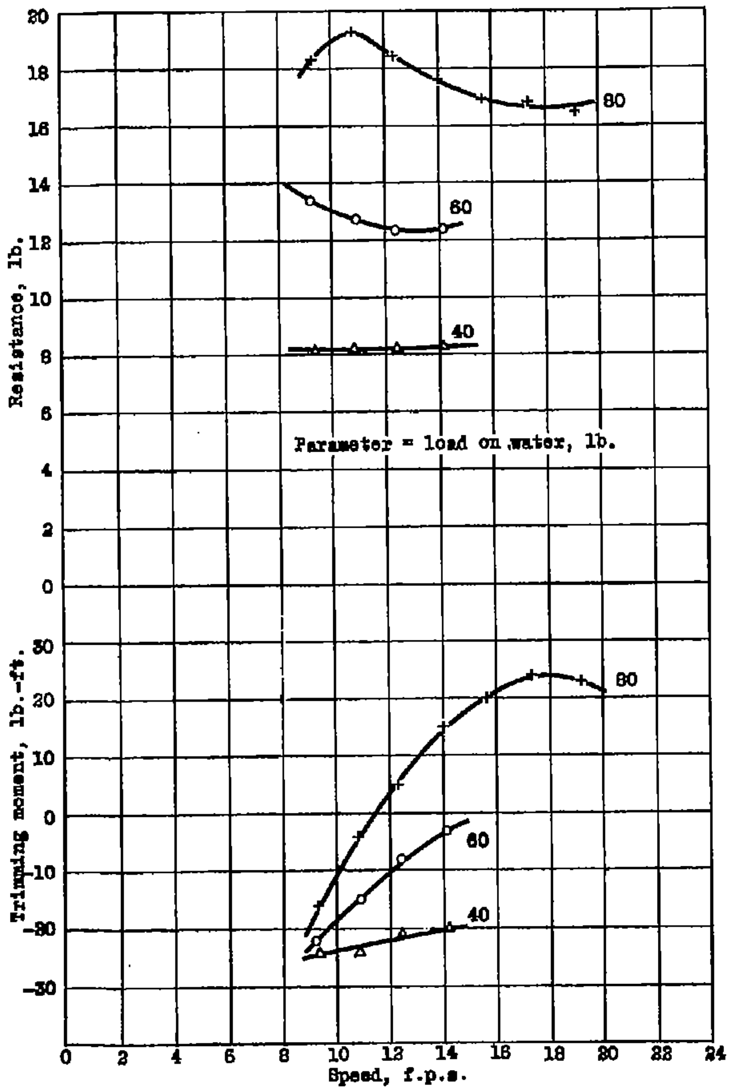

Figure 7.- Resistance and trimming moment. τ = 11°.
Model 22.

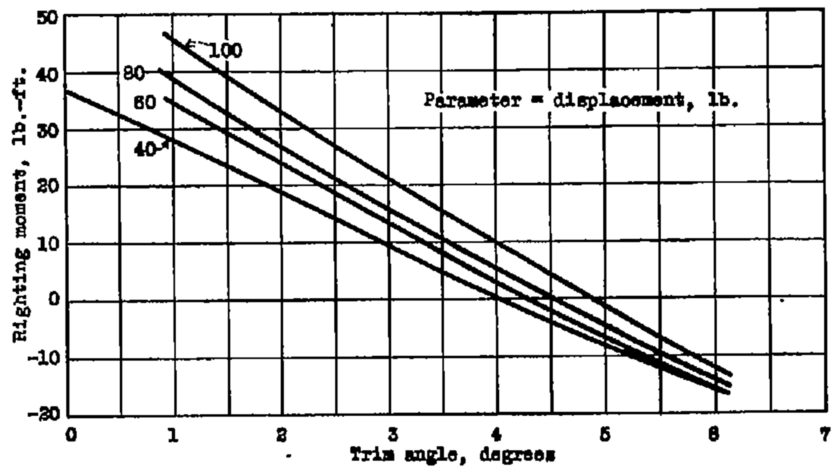

Figure 8.- Righting moments at rest.
Model 22.

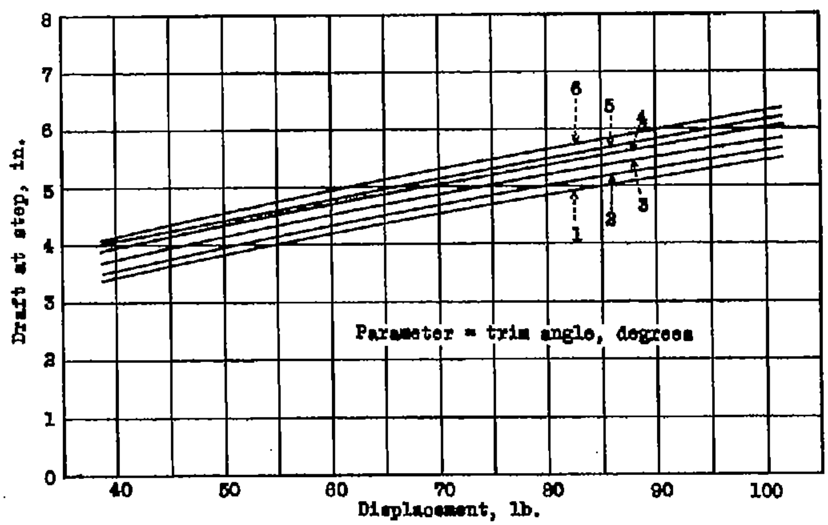

Figure 9.- Drafts at rest.
Model 22.

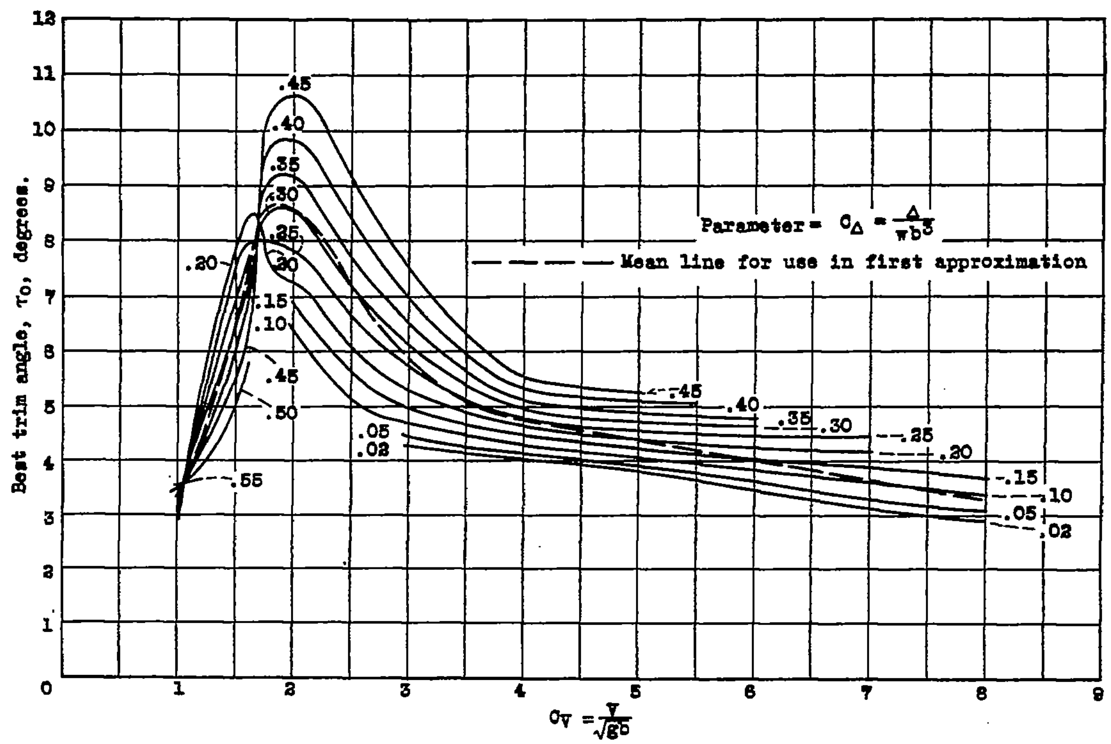

Figure 10.- Variation of best trim angle, τ_o, with C_V. Model 22.

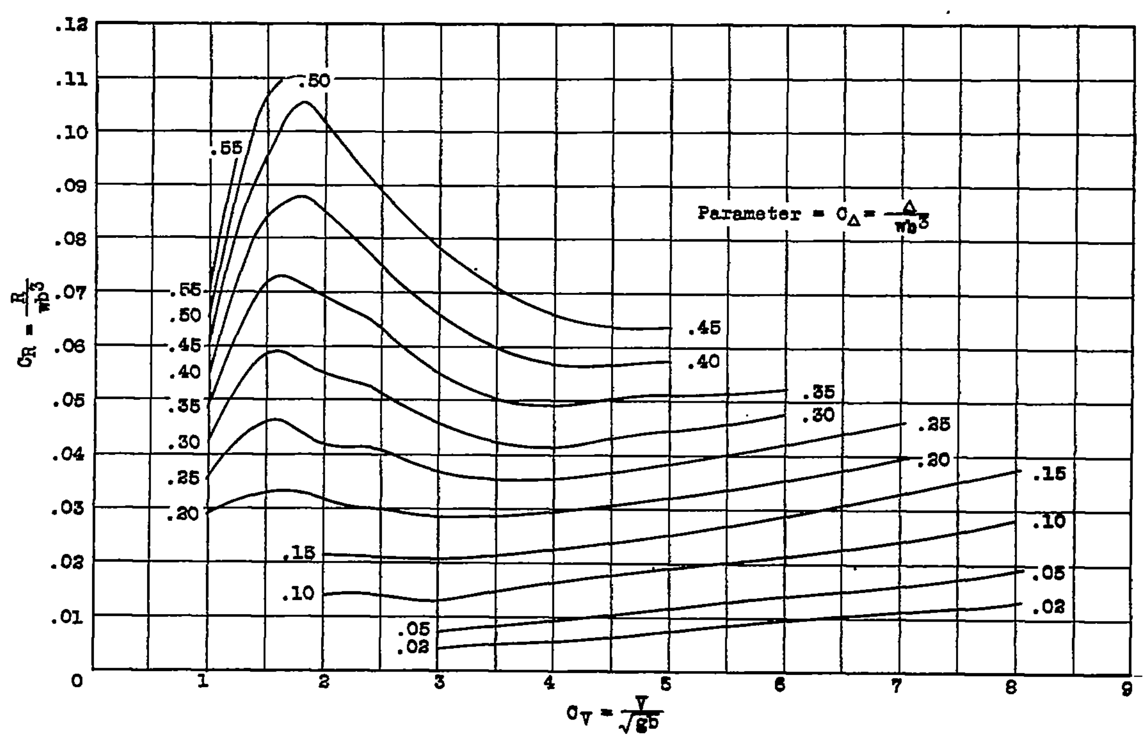

Figure 11.- Variation of C_R with C_V at best trim angles. Model 22.

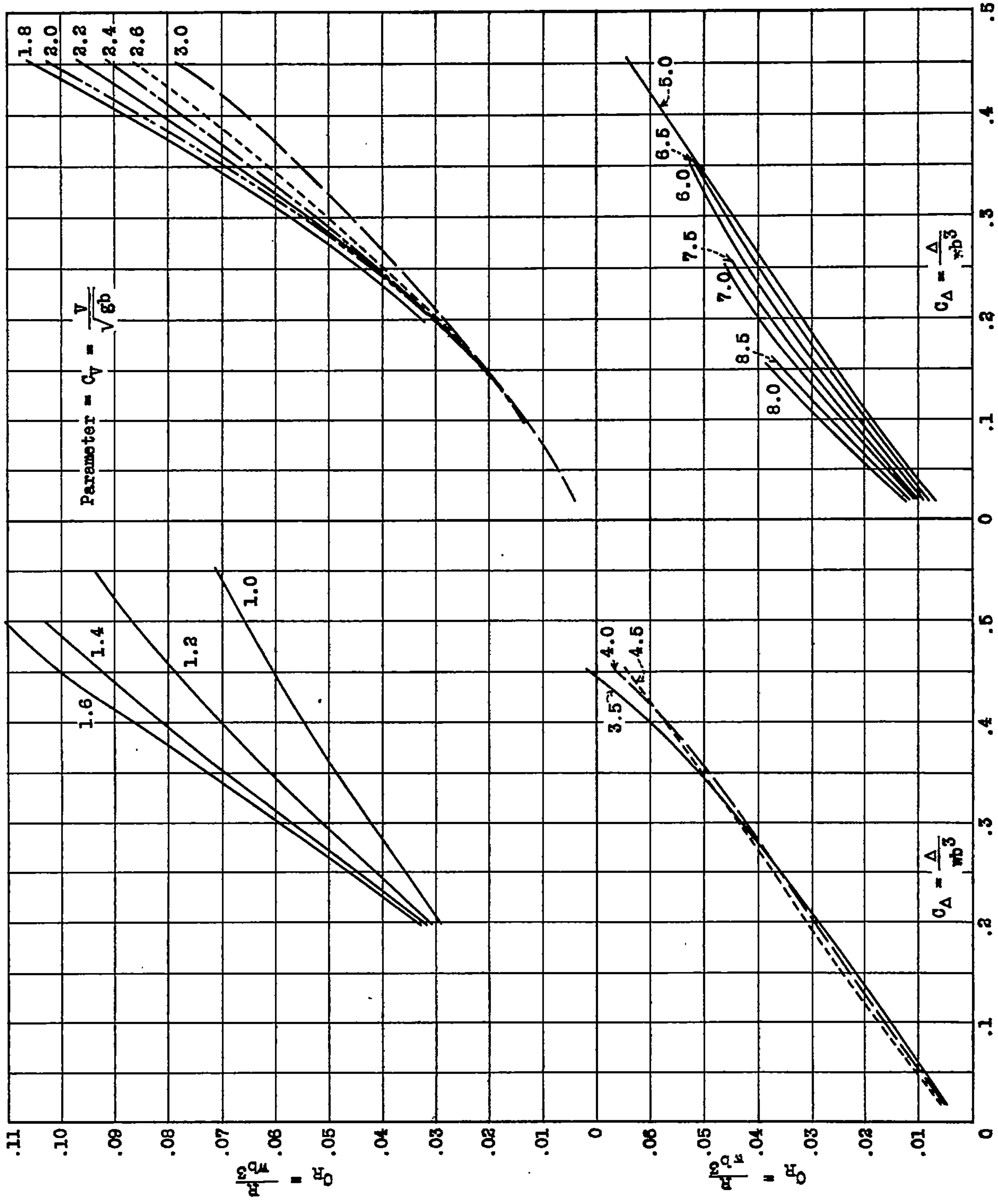

Figure 12.- Variation of C_R with C_Δ at best trim angles. Model 22.

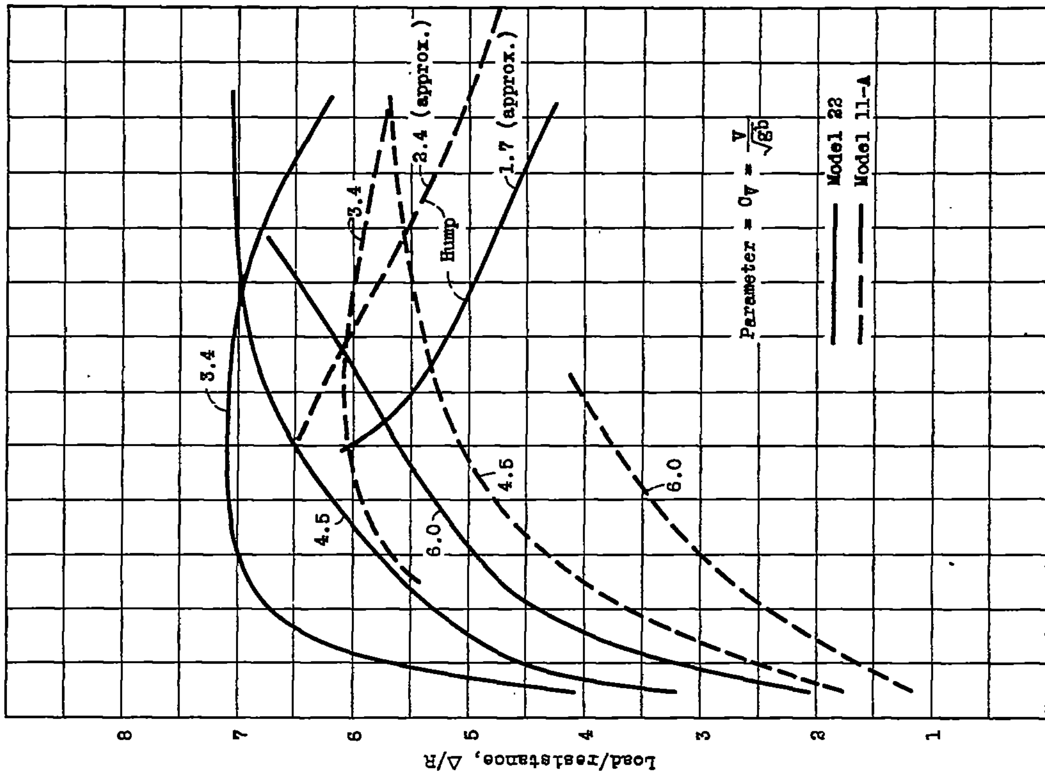

Figure 14.- Effect of C_Δ on Δ/R at best trim angles.

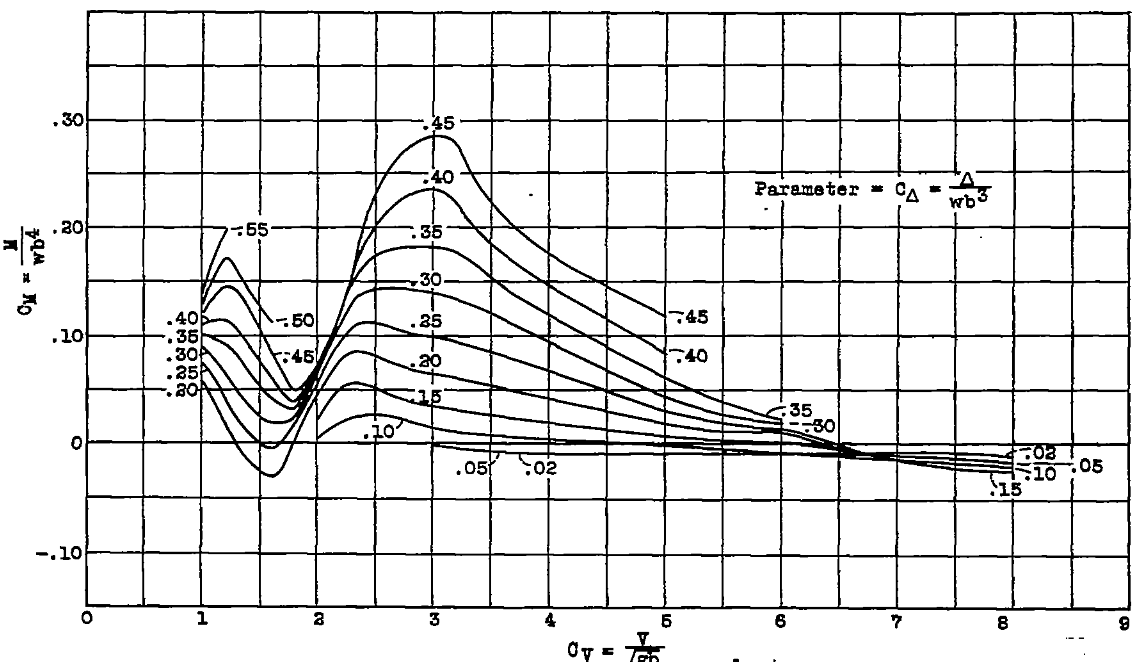

Figure 13.- Variation of C_M with C_V at best trim angles.
Model 22.

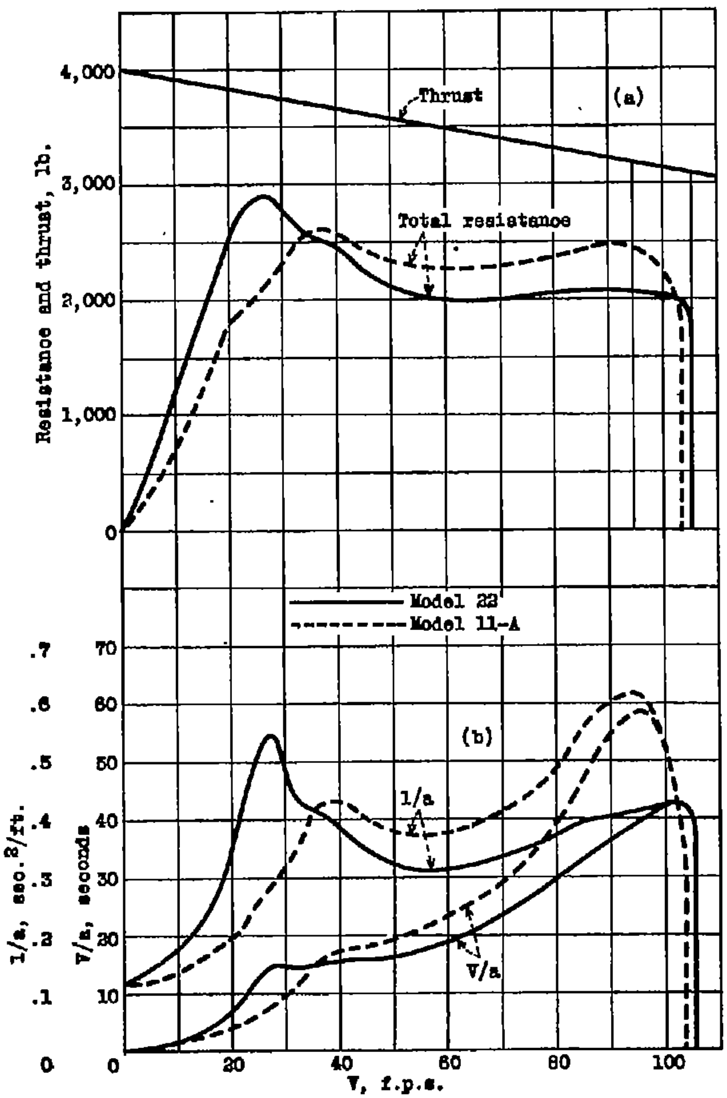

Figure 15.- Comparison between take-off performance of Models 22 and 11-A.

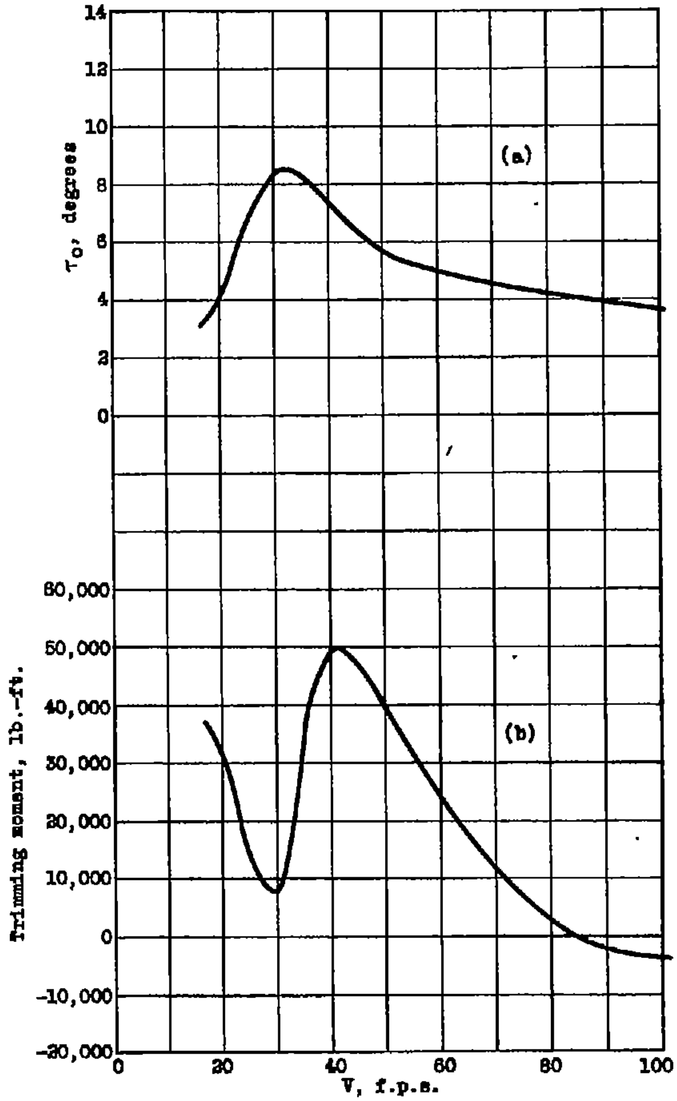

Figure 16.- Trim angles and trimming moments for 15,000-lb. flying boat using lines of Model 22.